SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay

Steven R. Ramp
CeNCOOS / MBARI
7700 Sandholdt Road
Moss Landing, CA 95039

Joseph Rice
Physics Department
Naval Postgraduate School
Monterey, CA 93943

Mark Stacey
Dept. of Civil and Env. Engineering
UC Berkeley
Berkeley, CA 94720

Toby Garfield
SFSU Romberg Tiburon Center
Tiburon, CA 94920

John Largier
UC Davis / Bodega Marine Laboratory
Bodega Bay, Ca 94923

Abstract - A pilot project was recently completed in the San Francisco Bay from May 1-10, 2009, to test the use of advanced moorings combined with undersea and wireless networking for displaying real-time environmental data online. The project was a collaboration among several universities and state and federal agencies and was hosted by SFSU's Romberg Tiburon Center (RTC) in Tiburon, CA. Two current profilers housed in hydrodynamic moorings were deployed near Angel Island to observe currents throughout the water column and transmit data to shore in real time via a communications gateway mounted on a US Coast Guard navigation buoy. The network was an implementation of the most recent version of the Seaweb system developed at the SPAWAR systems center in San Diego, CA. A series of undersea repeater nodes were used to transmit the signals from the sensors to the buoy using very low power outputs. Shipboard CTD and ADCP surveys were also completed to help understand the observed circulation. The long-term plan is to make these data available all the time at several key choke points within the bay and use it to constrain a new community model of the San Francisco Bay circulation being developed by UC Berkeley and Stanford University. The model output will in turn be used to address community needs in the areas for maritime safety, water quality, spill containment and mitigation, and ecosystem health. Instruments were deployed in Raccoon Strait and the Main Channel on May 1, 2009 and collected data for 10 days. The primary mooring structure was a new package developed at the Naval Postgraduate School that integrated current sensors, acoustic release, and acoustic modems into a Flotation Technologies Stablemoor moored 3 m off the ocean floor. This package allowed for the possibility of migrating sand waves about 2 m high, which could potentially prevent a bottom package from being recovered. Mooring performance was good, with a variance in pitch and roll of only about plus or minus 5 degrees in very high currents. Observed currents in the Main Channel were predominantly tidal and oscillated from the southwest to northeast at speeds exceeding 100 cm/s. Currents were barotropic over most of the tidal cycle but exhibited an unusual shear in the v-component for about 3 hours at the beginning of each ebb tide. Such shear in the water column is of interest to deep-draft vessels transiting the area. The Raccoon Strait observations were hampered by a failed compass in the instrument: It may be possible to reconstruct the record using the observed speed and the highly oscillatory nature of the flow. Plans are underway for a second, longer deployment in the bay during July 2009. These technologies can potentially allow for obtaining real-time current observations in difficult environments where they were not previously possible.

0-933957-38-1 ©2009 MTS

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2010	**N/A**	**-**

4. TITLE AND SUBTITLE **SF Bayweb 2009: Planting the Seeds of an Observing System in the San Francisco Bay**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **CeNCOOS / MBARI 7700 Sandholdt Road Moss Landing, CA 95039**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

See also ADM202806. Proceedings of the Oceans 2009 MTS/IEEE Conference held in Biloxi, Mississippi on 26-29 October 2009. U.S. Government or Federal Purpose Rights License., The original document contains color images.

14. ABSTRACT

A pilot project was recently completed in the San Francisco Bay from May 1-10, 2009, to test the use of advanced moorings combined with undersea and wireless networking for displaying real-time environmental data online. The project was a collaboration among several universities and state and federal agencies and was hosted by SFSU's Romberg Tiburon Center (RTC) in Tiburon, CA. Two current profilers housed in hydrodynamic moorings were deployed near Angel Island to observe currents throughout the water column and transmit data to shore in real time via a communications gateway mounted on a US Coast Guard navigation buoy. The network was an implementation of the most recent version of the Seaweb system developed at the SPAWAR systems center in San Diego, CA. A series of undersea repeater nodes were used to transmit the signals from the sensors to the buoy using very low power outputs. Shipboard CTD and ADCP surveys were also completed to help understand the observed circulation. The long-term plan is to make these data available all the time at several key choke points within the bay and use it to constrain a new community model of the San Francisco Bay circulation being developed by UC Berkeley and Stanford University. The model output will in turn be used to address community needs in the areas for maritime safety, water quality, spill containment and mitigation, and ecosystem health. Instruments were deployed in Raccoon Strait and the Main Channel on May 1, 2009 and collected data for 10 days. The primary mooring structure was a new package developed at the Naval Postgraduate School that integrated current sensors, acoustic release, and acoustic modems into a Flotation Technologies Stablemoor moored 3 m off the ocean floor. This package allowed for the possibility of migrating sand waves about 2 m high, which could potentially prevent a bottom package from being recovered. Mooring performance was good, with a variance in pitch and roll of only about plus or minus 5 degrees in very high currents. Observed currents in the Main Channel were predominantly tidal and oscillated from the southwest to northeast at speeds exceeding 100 cm/s. Currents were barotropic over most of the tidal cycle but exhibited an unusual shear in the v-component for about 3 hours at the beginning of each ebb tide. Such shear in the water column is of interest to deep-draft vessels transiting the area. The Raccoon Strait observations were hampered by a failed compass in the instrument: It may be possible to reconstruct the record using the observed speed and the highly oscillatory nature of the flow. Plans are underway for a second, longer deployment in the bay during July 2009. These technologies can potentially allow for obtaining real-time current observations in difficult environments where they were not previously possible.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**8**	

I. INTRODUCTION

Direct observations of the currents, temperatures, and salinities in the San Francisco Bay are notoriously difficult due to the shallow water, high current speeds, heavy ship traffic, and abundance of marine detritus. Real-time observations are even more difficult due to the propensity for cable failures due to mechanical working and snagging from above. Nevertheless, there is a strong need for such observations, especially in constricted straits such as the Golden Gate, Raccoon Strait, and Carquinez Strait. The many user applications include ship loading and safe transit; oil spill prevention, response, and mitigation; eradication of invasive species; and habitat recovery. Previous attempts to observe the currents with internally recording acoustic Doppler current profilers (ADCPs) mounted in trapezoidal trawl resistant bottom mounts (TRBMs) have usually met with failure. While all the failure modes are unknown, it is suspected that many were buried by migrating sand waves along the bottom which often exceed 2 m in height. Even when functioning, these systems did not deliver the data in real time, which is essential for model data assimilation and forecasting.

To overcome these myriad shortfalls, an entirely new method of observing the currents in constricted, high-velocity straits was assembled and deployed in the Main Channel and Raccoon Strait during 1-10 May 2009. These sites were chosen for the demonstration due to their customer interest, environmental difficulty, and close proximity to the SFSU Romberg Tiburon Center (RTC), which served as the headquarters for the experiment. Operations at sea were professionally executed from the R/V QUESTUARY, owned and operated by RTC. On the science side, Raccoon Strait represents an important verification point for the new community bay circulation model presently being developed by UC Berkeley and Stanford University. Understanding the basic physics of the flow through the strait is essential for improving model predictive skill. Supplementary current, temperature, and salinity transects were also conducted in the region while the moored instruments were in the water, using a hull-mounted ADCP and a half-dozen conductivity-temperature-depth (CTD) stations. In the remainder of this paper we discuss the acoustic network, mooring hardware, data return, and some preliminary results.

II. DATA AND METHODS

The Seaweb acoustic network, installed by the Naval Postgraduate School with support from the SPAWAR Systems Center in San Diego, CA, consisted of the observing nodes, repeater nodes, and a gateway node mounted on a US Coast Guard (USGC) navigation buoy (Fig. 1). The cooperation from the U.S. Coast Guard, 11th District, Yerba Buena, CA was excellent: They deployed the cutter USCGC ASPEN to the region to recover the large buoy, install the communications gateway, and redeploy the buoy. This was done on April 27, in advance of the rest of the deployment. The rest of the gear including the ten repeater nodes and the two observing nodes was deployed on 1 May from the QUESTUARY. The nominal distance between repeater nodes was less than 1 km and the operating frequency for the entire network was 9-14 kHz.

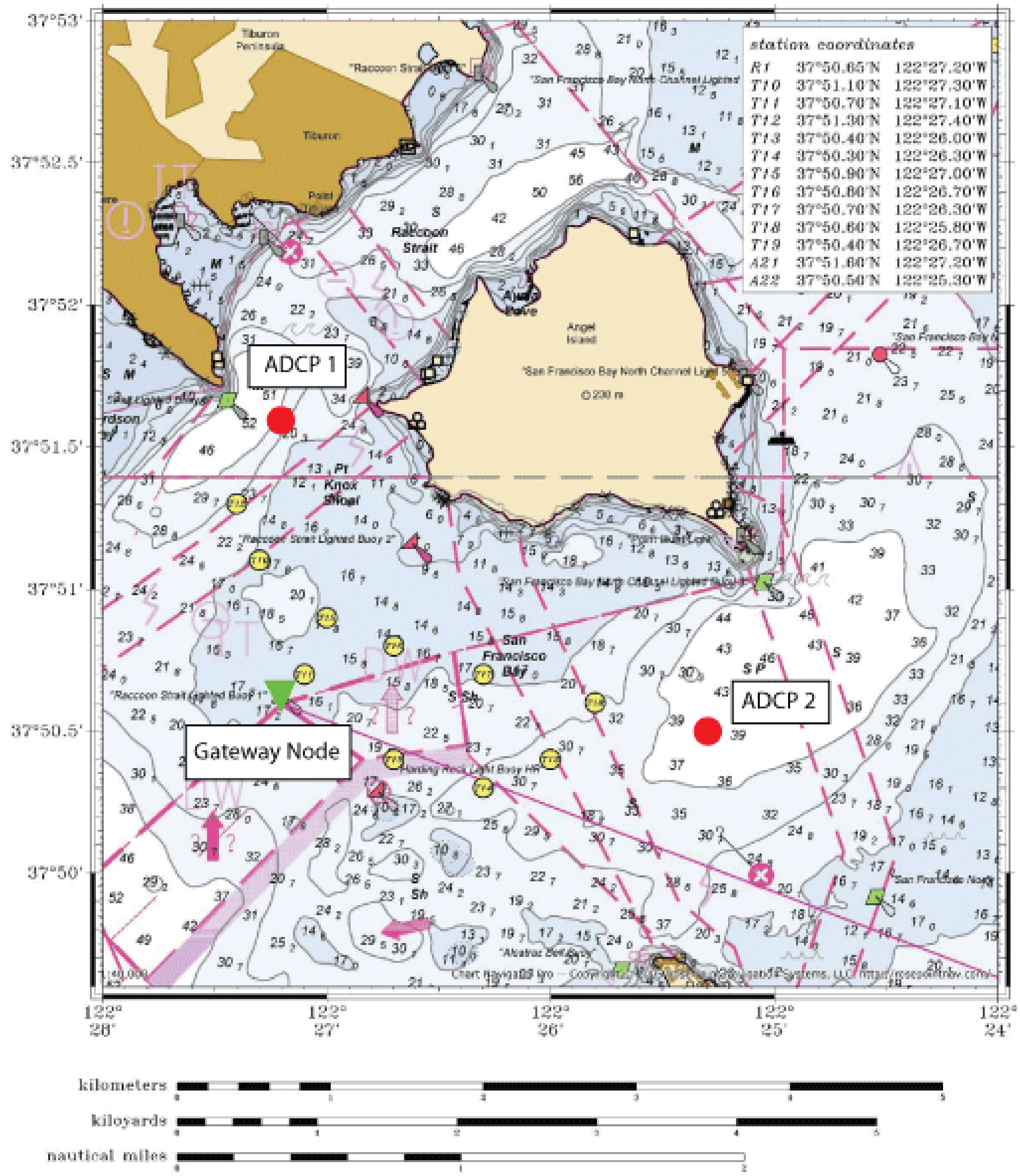

Figure 1. A locator map showing the two moorings, gateway buoy, and bottom repeater nodes. Site ADCP 1 is referred to subsequently as "Raccoon Strait" and ADCP 2 as the "Main Channel".

A novel aspect of the experiment was the development of a new, totally integrated package for observing currents and networking the data in a high-current, high-noise environment. All the instruments including the ADCP, acoustic modem, and acoustic release were bolted into special compartments in a hydrodynamic syntactic foam buoy designed to remain level in high currents (Fig. 2). The only mooring elements below the buoy were 3 m of chain and a 500 kg anchor. Using this configuration with the acoustic release housed in the buoy itself, the package would still come back to the surface even if 2-m sand waves migrated underneath the buoy. This package worked well, registering pitch and roll less than ± 5 degrees either way. Both units were successfully recovered on command.

Fig. 2. Photograph showing the observation node on deck of the R/V QUESTUARY. The modem transducer is the most forward item on top with the ADCP transducer heads behind. The top of the acoustic release is visible under the lifting bails behind the ADCP. The acoustic modem itself, not visible, is mounted in a cut-out along the port side.

The ADCPs, equipped with the new NEMO™ wave package, operated throughout the 10-day deployment sampling waves once per hour and currents every ten minutes. The Raccoon Strait instrument suffered a total compass failure, apparently the result of a firmware problem in the instrument. The Main Channel instrument worked well. The wave sampling algorithm from a moving platform was a curiosity: Further analysis is underway to determine if this information can be extracted via spectral analysis of the raw data. The acoustic networking was a learning exercise: It was indeed a very high noise environment, which could be heard immediately upon lowering the transducer head into the water. The source of this noise remains unknown. It could be pumping noise from municipalities nearby, reverberation from heavy shipping throughout the bay, or hydrodynamic noise from the currents themselves streaming over the shallow seas. There was some evidence for the latter, as modem connectivity seemed to improve slightly at slack water. However, this may also relate to the aspect presented by the repeater nodes under blow-down by high currents, which reduced network efficiency during the maximum tidal currents. Additional research is needed to determine the source of this noise, and how to deal with it for undersea networking purposes. There were also several firmware failures associated with the latest, upgraded acoustic modems. The result of the high noise and firmware problems was no real-time data transmission during this exercise. The hardware problems are being diagnosed and will hopefully be fixed in time for a second similar exercise scheduled for July – August 2009.

III. RESULTS

Despite the technical challenges, a truly unique time series was recorded internally by the Main Channel ADCP. The tidal currents were slightly stronger on ebb than flood, ranging from +100 to -150 cm/s (Fig. 3). Interestingly, the flow was not always barotropic. This result is highlighted by the stick vector plots of the surface currents over the bottom currents, with the times when the two were in opposition highlighted in pink (Fig. 4). This may be due to a wake eddy which develops off Angel Island during the ebb tide. This information was of high interest to the oil spill response community, since a significant fraction of the oil during the recent COSCO BUSAN spill was heavier than water and went to the bottom. Surface currents alone would provide helpful, but incomplete information when responding to a spill. Since information product development is important to CeNCOOS, alternative displays which are more accessible to managers and the general public were also created. These may be viewed live on the CeNCOOS web site at http://www.cencoos.org/sections/conditions/sfbayweb/sfbayweb.shtml.

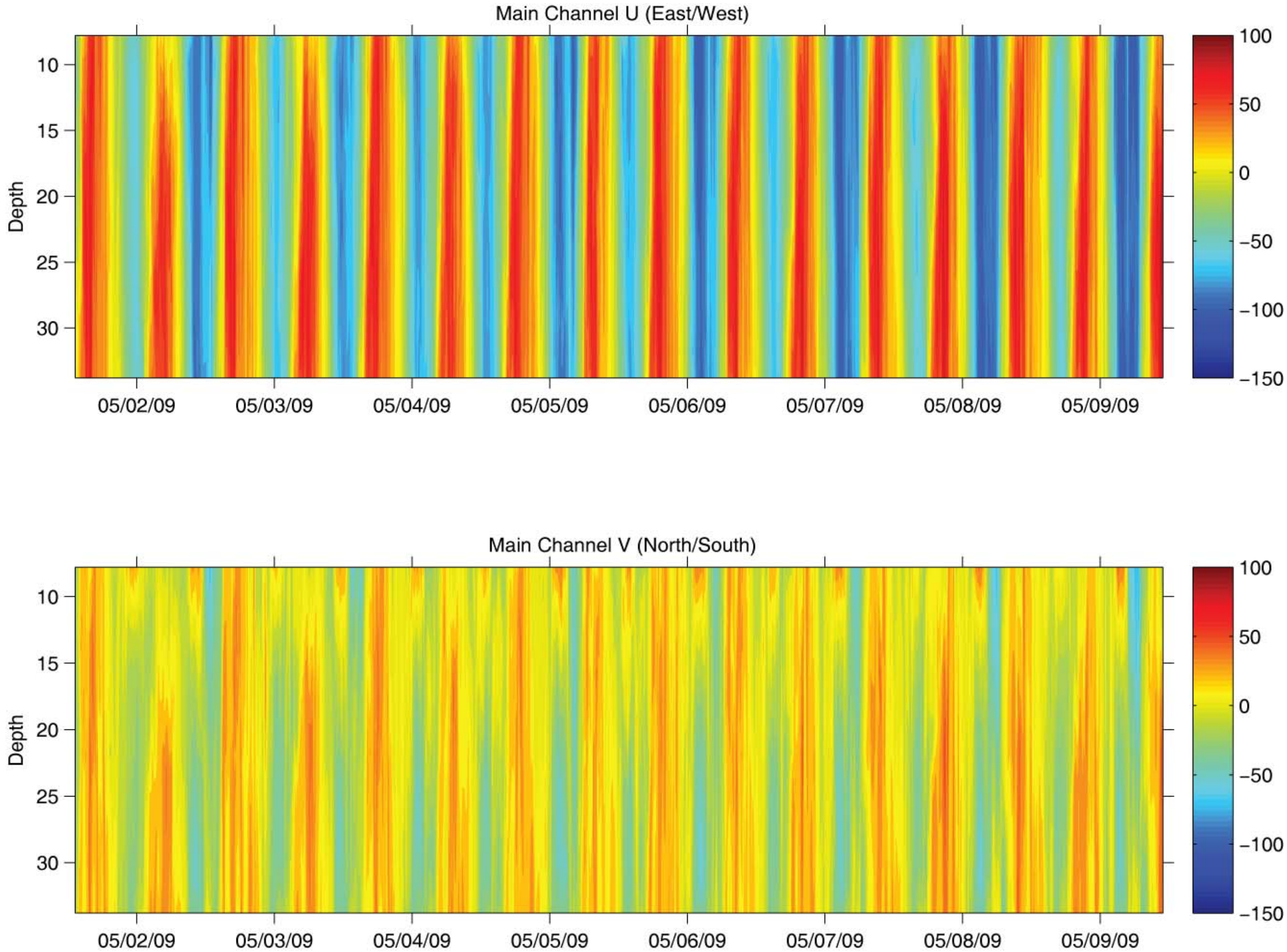

Fig. 3. The east/west (top) and north/south (bottom) current components from the Main Channel. The flood tide is towards the northeast and the ebb tide is towards the southwest. The tidal currents were nearly uniform vertically in the east/west direction but not in the north/south direction. At the beginning of each ebb (southward) tide, an unusual shear structure appeared when the flow was still northward at the surface but southward at the bottom. The current then became southward throughout the water column until the tide turned to flood once again.

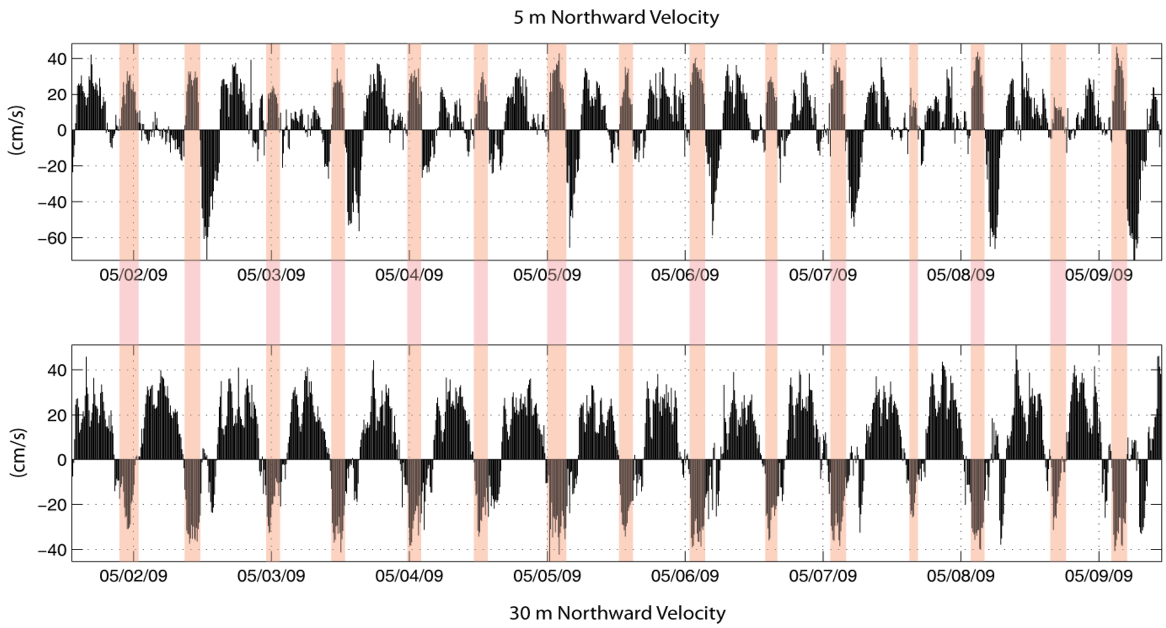

Fig. 4. Current vectors for the north/south component of the current in the Main Channel near the surface (5 m, top panel) and near the bottom (30 m, bottom panel) highlighting the times when the surface and bottom currents were opposed. The scale indicates the strength of the current. Upward-pointing lines are northward (flood tide) and downward-pointing lines are southward (ebb tide). The ebb/flood pattern is much clearer at the bottom than at the surface. This regular pattern of opposing currents occurred at the beginning of each ebb tide.

The current sections along the axis of Raccoon Strait obtained from the hull-mounted ADCP on the R/V QUESTUARY were also quite illuminating. These sections (see locator map Fig. 5) showed flow separation over the top of the sill during the strong ebb tide, indicating possible hydraulic control in the strait (Fig. 6). This would limit the amount of transport possible through the strait, forcing some percentage of the flow to divert to other channels. This represents critical information for constructing a successful numerical model of the circulation in the bay.

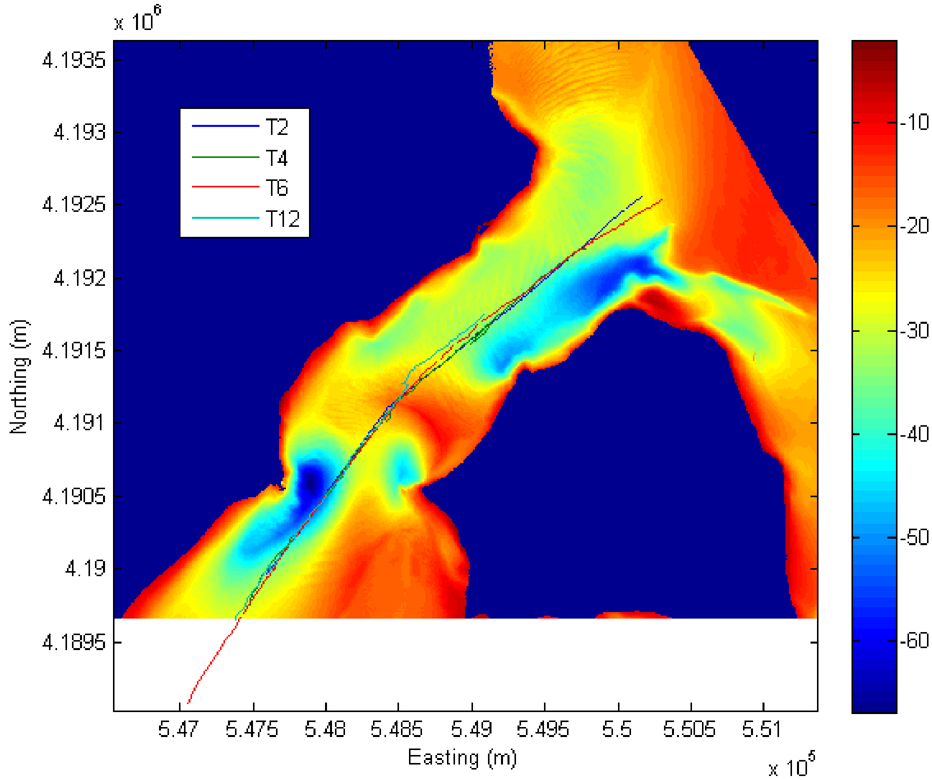

Fig. 5. Locator map for ADCP transects in Raccoon Strait between Angel Island (right) and the Tiburon Peninsula (left).

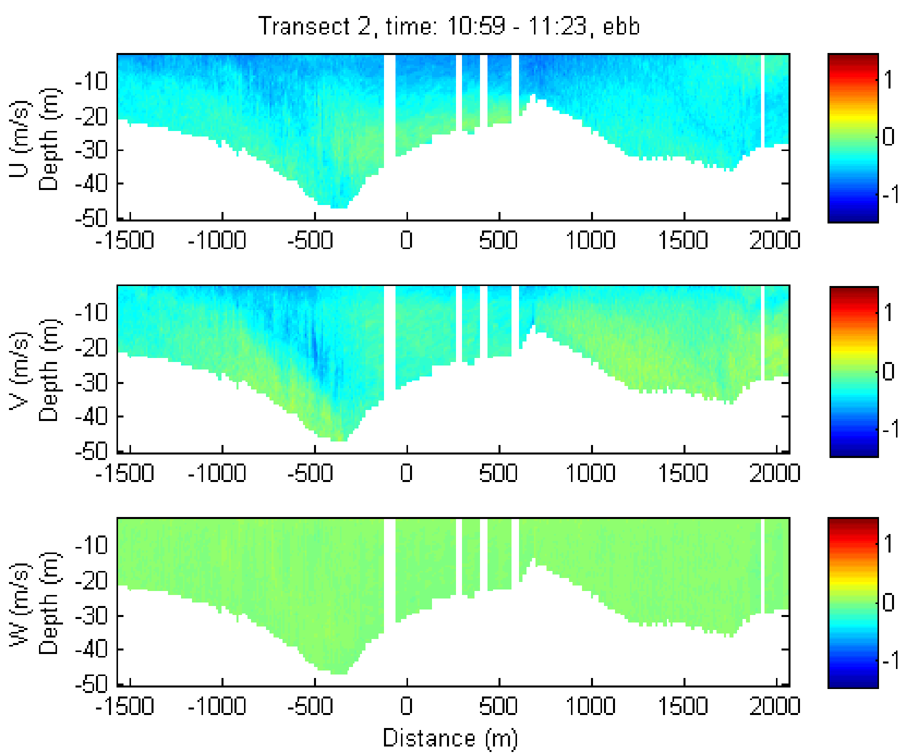

Fig. 6. Shipboard ADCP transects through Raccoon Strait. The view is northwest with southwest to the left and northeast on the right. The dark blue tones indicate strong ebb tide towards the southwest over the top of the sill.

IV. CONCLUSIONS

A pilot experiment to demonstrate the feasibility of real-time acoustic networking of current sensors in the San Francisco Bay was completed during Apr. 27 to May 10, 2009. While a difficult environment was chosen intentionally, it proved to be even more difficult than imagined. The live networking was unsuccessful yet many important lessons were learned, and improvements to the system for next time were made. The time series recorded internally by the ADCPs and the data from the shipboard surveys proved quite valuable in our drive towards understanding the physics of the bay circulation. The collaboration by all participants was outstanding and paves the way for future cooperative efforts in the bay.

ACKNOWLEDGMENTS

The team thanks Prof. Toby Garfield, Director of RTC, for providing both work space and office space for the experiment. The RTC Marine Superintendent and Captain, David Bell and David Morgan, provided invaluable advice and support. Mr. Fred Bahr of CeNCOOS set up the ADCPs. The Seaweb team from SPAWAR Systems Center, Bill Marn, Bob Creber, and Chris Fletcher, set up the network and deployed and recovered the system. Megan Williams at UC Berkeley assisted with the ship surveys and data processing. The cooperation from the U.S. Coast Guard recovering and redeploying the navigation buoy to install the gateway node was outstanding. Funding for this exercise was mostly cooperative. Significant funding was provided however by the U.S. Navy via the Naval Postgraduate School and the SPAWAR Systems Center. S. R. Ramp and F. L. Bahr were partially supported by the ONR Physical Oceanography Program and by NOAA via CeNCOOS.